EXPERIMENTAL STUDY OF DURATION OF CONTACT OF A TRANSVERSELY IMPINGING LOAD ON CANTILEVER

B. B. BANERJEE

PHYSICS LABORATORY, UNIVERSITY COLLEGE OF ENGINEERING, BURLA (ORISSA).

(*Received* 11 July, 1963)

ABSTRACT. In this paper the variation of duration of contact for two metal hammers striking transversely a mild steel rod, fixed at one end from respective particular distances, has been photographically studied. The time is recorded by the shadow-graph of a light pointer attached to an electrically maintained tuning fork of frequency 100. The duration of impact has been found to vary discontinuously with striking distances measured from fixed end of the cantilever. The phenomenon of multiple or double contacts within the period of impact has been observed in almost all cases. This seems to be due to fluctuating pressures caused by reflected transverse waves from both ends producing reactions on the hammer. In every photograph the vibration curve of a section of the rod is fluctuating over the general sine curve. This shows that vibrations have set in the rod during impact itself. These observations will help settle many outstanding problems in the vibration of cantilevers and lead to a correct theoretical understanding of the problem.

INTRODUCTION

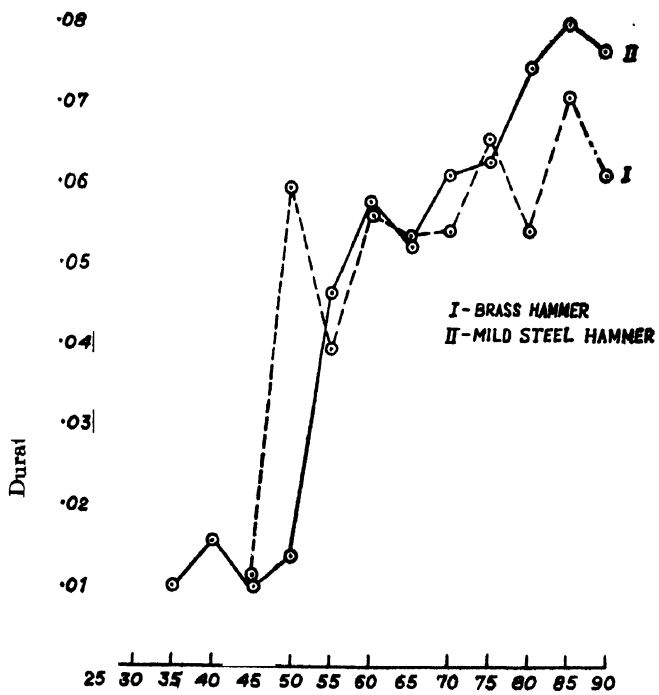
Rayleigh and St. Venant by the help of the normal function tried to give theoretical explanation of the free vibration of a bar including a fixed-free bar permanently loaded at the free end. Morse has considered the case when the vibration is set up by initial velocity. Timoshenko has considered the Hertzian impact between the bar and transversely impinging load. M. Ghose and K. D. Roy tried to study the dynamics of the vibration of a bar excited by transverse impact of a load and obtained the expression for duration of impact. Their analysis is not however complete to explain the experimental facts which are observed and reorded in this paper. No detailed experimental observation has been on record so far. The results of the observations made in this paper may lead to correct theoretical approach to this problem.

EXPERIMENTAL

In this paper we record some of our experimental observations of systematic study of the problem. The experimental study of the duration of impact for different mass of the hammer striking transversely at different points of a cantilever has been made by photographic method. The experimental arrangement for recording the duration of impact is similar to that adopted by M. Ghose in the study of struck string. Elegance of this method over other methods is that the photograph obtained by a moving camera clearly records the complete behaviour of the cantilever at successive stages during impact.

A mild steel rod of length 90 cms. and diameter 1.27 cms. is fixed rigidly at one end in a heavy iron pillar, whose base being embedded in concrete in order to ensure that there is no yielding at the fixed end. The rod is found to remain horizontal. This has been thoroughly tested by the help of a spirit level. A pendulum with bifilar suspension is used for the impinging load. The shadows of the rod, the pointer of an electrically maintained tuning fork of frequency 100 for time base and the impinging load are simultaneously photographed on the moving photographic paper on trolley inside the camera box. The system is illuminated by an arc lamp from the top.

Ample precautions are taken during experiment such that the load strikes the rod perpendicularly and that there is no overlapping of the shadows of the load and the rod just before and after contact otherwise this would introduce serious error in the measurements. In order to obtain the simultaneous photograph of the impinging load and the rod. sufficient care has been taken in releasing the photo carrier with its trolley and the impinging load in time from their respective mechanical catches.



→ Striking distance in cms.

Fig. 1.

TABLE I

Brass hammer—Spherical.
Weight of hammer—240 gms.
Radius of curvature of surface of contact 1.905 cms.
Velocity before impact : 88.5 cms./sec.

Striking distance in cms.	Duration of successive contacts in secs.	Duration of separation in secs.	Duration of impact in secs.	Striking distance in cms.	Duration of successive contacts in secs.	Duration of separation in secs.	Duration of impact in secs.
45	.00304				.00199		
		.00361	.01107	70		.02493	
	.00442				.00263		.05421
						.01971	
					.00495		
	.00531			75	.00516		
50		.00374				.01683	
	.00621		.05960		.00865		.06659
		.03730				.00373	
	.00704				.03222		
55	.00599			80	.00319		
		.00221				.01263	
	.00345		.03965		.01236		.05385
		.02161				.00546	
	.00639				.02021		
60	.00513			85	.01208		
		.03243				.01220	
	.00370		.05558		.01997		.07097
		.01086				.00455	
	.00346				.02217		
65	.00527				.00597		
		.02195				.01089	
	.00740		.05351	89	.01168		
		.01542				.02266	.06165
	.00347				.00324		
						.00131	
					.00590		

The hammer is released mechanically from a fixed distance to keep the velocity of impact constant. It strikes the rod at a point the distance of which is measured from the fixed end of the rod. The observations are made at points 5 cms. apart, the last one being at 89 cms.

The measurements of duration of contact and duration of separation have been made by a comparator reading upto .0001 cm. The number of waves traced just overhead by the fork of frequency 100, within the same length of the hammer's shadow in contact with that of the rod, helps to measure the duration of impact or separation during impact.

DISCUSSION AND RESULTS

The durations of impact for different struck points and for different hammers are given in tables I and II. It is found that in almost all cases there are double or multiple contacts before the hammers finally leave the rod. It is obvious that these phenomena are due to the influence of the reflected waves from the ends that overtake the hammer. The duration of impact is a root of the pressure equation $P = f(t) = 0$, of the load. This equation may have multiple roots of which more than one may be real and positive. In that case it is more logical to define the real duration of impact as the greatest real positive root of the equation $f(t) = 0$. After this maximum value of the root, the pressure becomes negative, and the load leaves the rod completely.

TABLE II

Weight of hammer—mild steel—233 gms.
Radius of curvature of the surface of contact—2.432 cms.
Velocity before impact : 99 cms/sec.

Striking distance from fixed end in cms	Duration of successive contacts in secs.	Duration of separation in secs.	Total duration of Impact in secs.	Striking distance in cms.	Duration of successive contacts in secs.	Duration of separation in secs.	Total duration of Impact in secs.
35	.00386			65	.00819		
		.00297	.00994			.03531	.05217
	.00311				.00867		
40	.01044			70	.00443		
		.00253	.01588			.02242	
	.00291				.00850		.06160
						.01056	
					.01569		
45	.00283			75	.01108		
		.00297	.01054			.00738	.06246
	.00474				.04400		
					.00268		
50	.01371	×	.01371	80		.00306	
					.00441		.07409
						.00980	
					.05414		
55	.00482			85	.01091		
		.00344				.01743	
	.00555		.04619		.01865		.07980
		.02047				.01046	
	.01191				.02235		
60	.00667			89	.01124		
		.03117	.05766			.02029	
	.01982				.01570		
						.00953	.07680
					.00715		
						.00570	
					.00719		

Column (1) shows the position of contact on the rod measured from the fixed end. Column (2) shows the duration in seconds of respective contacts. Column (3) shows the duration of separation in seconds which is the time between two successive contacts. Column (4) shows the duration of impact, measured from the instant the hammer makes first contact with the rod to the time when it completely leaves it. It is same as the sum of the time of all the contacts and the time during which the load does not remain in contact with the rod as depicted by black patches within the shadow graph (Fig. 2).

Graphical representation (Fig. I) of variation of duration of impact with striking distance shows that duration of impact changes discontinuously with the striking distance and tends to minimum as the fixed end is approached. The two striking loads of different materials depict slightly different character in

Brass Hammer

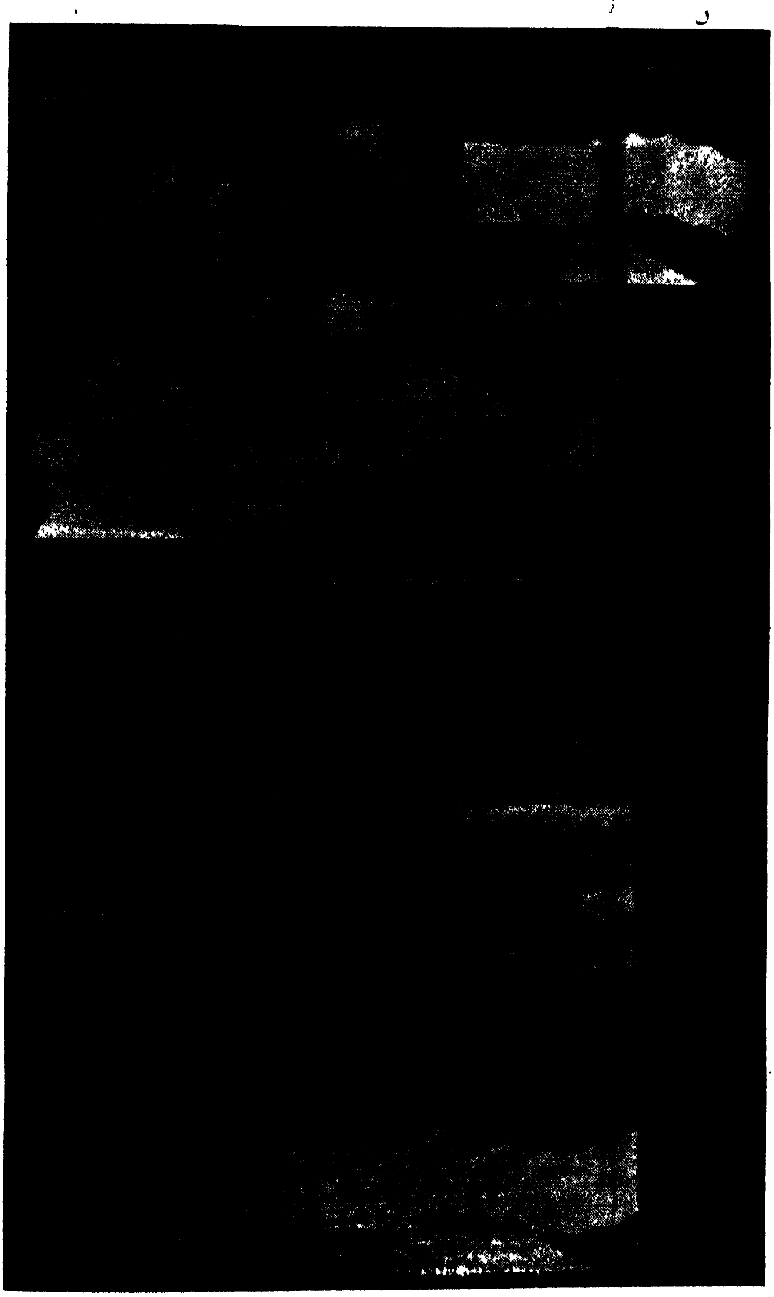


Fig. 2.

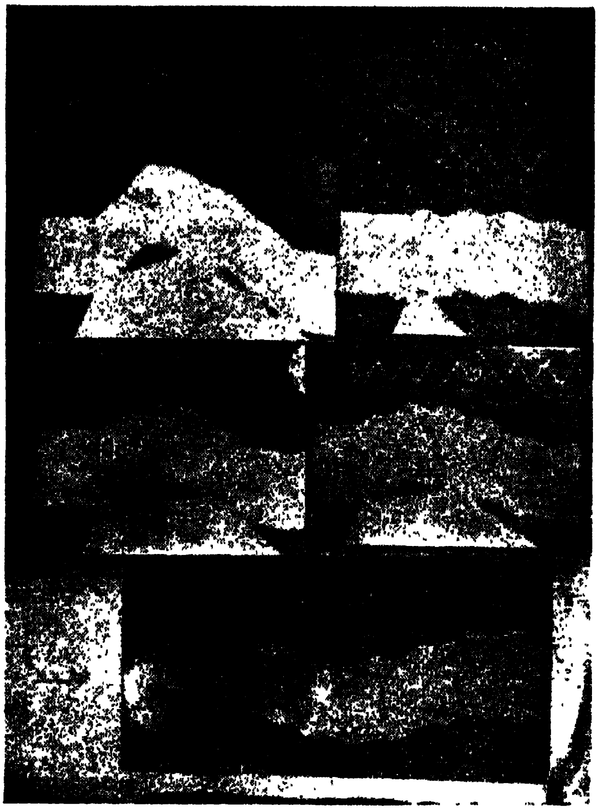
the behaviour of duration of impact though their general behaviours are similar. This difference may be due to the fact that they are different in weight and material and were impinged with different velocities.

It is evident from the observations of multiple contacts within the period of impact that pressure of impact fluctuates. This can not be explained by analyses given by Rayleigh, M. Ghose and K. D. Roy or Timoshenko. It suggests that transverse waves are generated in the rod which on travelling along the rod are

Mild Steel Hammer

89 cms

60 cms



35 cms

55 cms

40 cms

Fig. 3.

reflected from the ends and produce reaction on the load. In this way there may be successive reflections before the load completely leaves the rod; hence there are multiple contacts. None of the existing theories is able to explain the above fluctuations of pressure during impact as observed photographically.

The photographs show that the rod begins to vibrate as soon as impact begins. The vibration curves after impact show that some overtones are present along with the fundamental which is evident from fluctuating nature of vibrations over the general sine curve. The theoretical explanation of the same is in progress and will be published in due course. Experimental study of the different aspects of the problem is also in progress and will be reported in short time.

ACKNOWLEDGMENT

My best thanks are due to Dr. M. Ghose, D.Sc., Vice-Principal and Head of Physics Department, City College, Calcutta, for his suggestion of the problem and continuous guidance during the course of this work. I extend my thanks to Sri B. Mohapatra, Principal, Utkal University College of Engineering, Burla. (Orissa) for his extending all facilities to me in preparing this paper.

REFERENCE

Ghose, M. 1932, *Indian Journal of Physis*—Vol. 7, 5.

Ghose M. and Roy K. D. 1952, *Indian Journal of Theoretical Physics*—Vol. XXVI, 9,

Morse—Vibration and sound, Ch. IV.

Rayleigh—Theory of Sound Vol. I, 168 and 182.

St. Venant, 1883, Théorie de l'élasticité des corps solides, Paris, 298.

Timoshenko—Vibration problems in Engineering, 411.